AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. CONTRACT ID CODE	PAGE OF PAGES
J	1 | 23

2. AMENDMENT/MODIFICATION NO.	3. EFFECTIVE DATE	4. REQUISITION/PURCHASE REQ. NO.	5. PROJECT NO.(If applicable)
0006	11-Apr-2005		

6. ISSUED BY CODE N00174	7. ADMINISTERED BY (If other than item 6) CODE
NAVSEA INDIAN HEAD 101 STRAUSS AVE. ATTN: BRENDA PRICE 1143B BRENDA.PRICE@NAVY.MIL INDIAN HEAD MD 20640-5035	See Item 6

8. NAME AND ADDRESS OF CONTRACTOR (No., Street, County, State and Zip Code)

X	9A. AMENDMENT OF SOLICITATION NO. N00174-05-R-0018
X	9B. DATED (SEE ITEM 11) 04-Feb-2005
	10A. MOD. OF CONTRACT/ORDER NO.
	10B. DATED (SEE ITEM 13)

CODE FACILITY CODE

11. THIS ITEM ONLY APPLIES TO AMENDMENTS OF SOLICITATIONS

[X] The above numbered solicitation is amended as set forth in Item 14. The hour and date specified for receipt of Offer [ ] is extended, [X] is not extended.

Offer must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation or as amended by one of the following methods:
(a) By completing Items 8 and 15, and returning 1 copies of the amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE PLACE DESIGNATED FOR THE RECEIPT OF OFFERS PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided each telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

12. ACCOUNTING AND APPROPRIATION DATA (If required)

13. THIS ITEM APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS.
IT MODIFIES THE CONTRACT/ORDER NO. AS DESCRIBED IN ITEM 14

A. THIS CHANGE ORDER IS ISSUED PURSUANT TO: (Specify authority) THE CHANGES SET FORTH IN ITEM 14 ARE MADE IN THE CONTRACT ORDER NO. IN ITEM 10A.

B. THE ABOVE NUMBERED CONTRACT/ORDER IS MODIFIED TO REFLECT THE ADMINISTRATIVE CHANGES (such as changes in paying office, appropriation date, etc.) SET FORTH IN ITEM 14, PURSUANT TO THE AUTHORITY OF FAR 43.103(B).

C. THIS SUPPLEMENTAL AGREEMENT IS ENTERED INTO PURSUANT TO AUTHORITY OF:

D. OTHER (Specify type of modification and authority)

E. IMPORTANT: Contractor [ ] is not, [ ] is required to sign this document and return ____ copies to the issuing office.

14. DESCRIPTION OF AMENDMENT/MODIFICATION (Organized by UCF section headings, including solicitation/contract subject matter where feasible.)

SEE PAGE 2

Except as provided herein, all terms and conditions of the document referenced in Item 9A or 10A, as heretofore changed, remains unchanged and in full force and effect.

15A. NAME AND TITLE OF SIGNER (Type or print)		16A. NAME AND TITLE OF CONTRACTING OFFICER (Type or print) TEL: EMAIL:	
15B. CONTRACTOR/OFFEROR (Signature of person authorized to sign)	15C. DATE SIGNED	16B. UNITED STATES OF AMERICA BY (Signature of Contracting Officer)	16C. DATE SIGNED 11-Apr-2005

EXCEPTION TO SF 30
APPROVED BY OIRM 11-84

30-105-04

STANDARD FORM 30 (Rev. 10-83)
Prescribed by GSA
FAR (48 CFR) 53.243

SECTION SF 30 BLOCK 14 CONTINUATION PAGE

The following items are applicable to this modification:
PAGE 2

1. APPENDIX B: CELL CONTROL & INSTRUMENTATION, TO THE STATEMENT OF WORK, IS HEREBY DELETED IN IT'S ENTIRTY AND REPLACED WITH THE ATTACHED APPENDIX B: CELL CONTROL & INSTRUMENTATION.

2. SECTION H, CLAUSE HD 126 – GOVERNMENT – FURNISHED PROPERTY IS REVISED TO INCLUDE THE FOLLOWING:

   FADEC

   ALL DRAINS AND COMMON HARDWARE, TO INCLUDE THE BELLMOUTH AND OTHER SUCH ITEMS WILL BE GFP

   THE ENGINE DRESS KIT ITEMS WILL BE FURNISHED BY CCAD. ITEMS SUCH AS THERMOCOUPLES SHOULD BE PROVIDED BY THE CONTRACTOR. ALL STANDARD HARDWARE ITEMS AND THE BELLMOUTH, ETC., WILL BE GFM

3. SECTION J, DATA REQUIREMENTS ARE REVISED AS FOLLOWS:

   Project Schedule is Data Item A005. System Drawings-Installation is redesignated as Data Item A009.

   Progress Reports is Data Item A006. System Drawings-As-Built is redesignated as Data Item A010.

   Test Acceptance Software is Data Item A007. System Drawings-Vendor Information is redesignated as Data Item A011.

   Source Codes, Firmware, Software (Including Backup) is Data Item A008. System Manuals-Operations Manual is redesignated as Data Item A012.

APPENDIX B

APPENDIX B: CELL CONTROL & INSTRUMENTATION

1. Requirements

The specific requirements for the C&I system are provided in the following sections.

1.1 C&I System Definition and Description

The primary component of the C&I system is the data acquisition function of the test cell, which acquires important engine performance parameters in real-time while the engine is running. Average of 5 points of the data are then analyzed by the engine manufacturers' Data Reduction Programs (DRPs) as required. The C&I system also provides test cell operators with the ability to control the testing according to step-by-step acceptance test procedures provided by the engine manufacturers. Control hardware includes throttle and governor levers, load torque control, switches/contact closures, potentiometer adjustments, and control computer keyboard interface.

1.2 C&I System Block Diagram

A block diagram of the C&I system within the engine test cell is depicted in Figure 3-1. The C&I System does not include the engine water brake load, certain test cell facilities and fixtures, or the computers which host the DRPs. The C&I system must contain a multi-channel, real-time data acquisition system, and must be able to display this information on computer monitors for two operators ("pilot" and "co-pilot"). The data acquisition system must include signal conditioning as required for a variety of transducers and sensors in the test cell. The data acquisition system, operator controls, operator displays, signal conditioning, and the control computer are to be located in the control room of the test cell. Some transducers and sensors are provided as part of the engine under test, and some are Government Furnished Equipment (GFE), but most must be included in the C&I system acquisition. Some sensor and control components must be purchased from the OEMs (G.E. and Honeywell) of the engines to be tested. All wiring and cabling from the control room to the sensors, transducers and control hardware are also part of the C&I system.

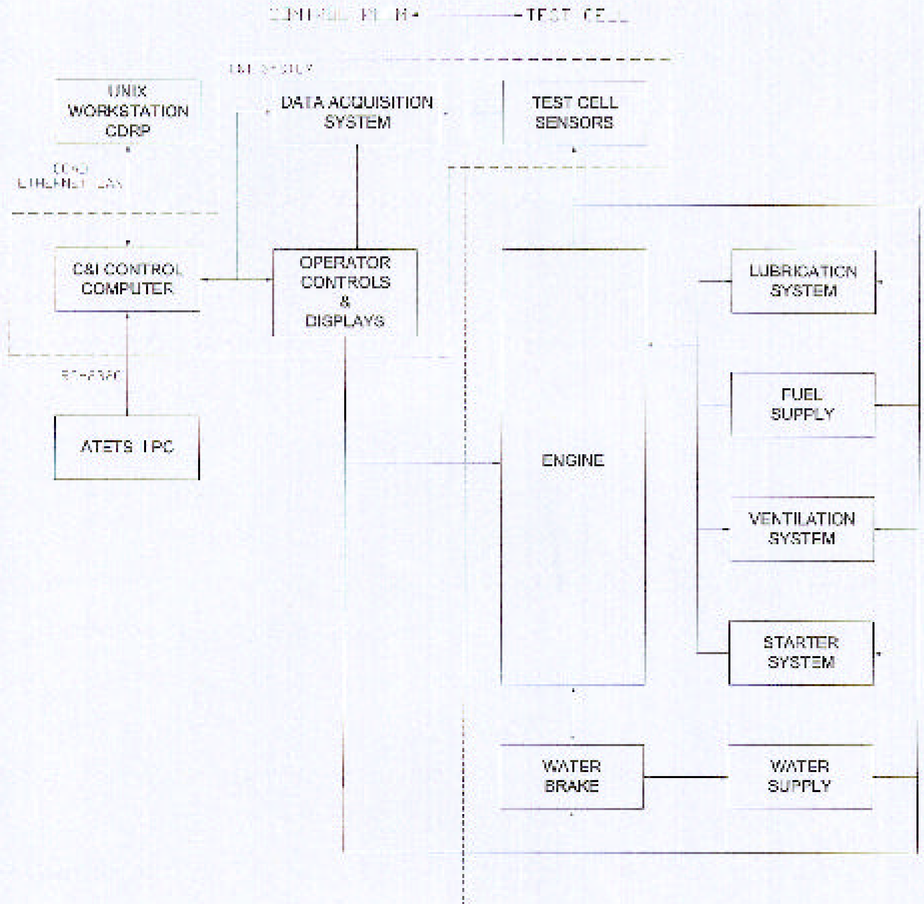

Figure 3-1. Test Cell C&I System Block Diagram

1.3 System Hardware Components

The Test Cell C&I hardware is comprised of four major components.

- **Data Acquisition System.** Used to measure data from sensors and convert to digital values in real time. Includes signal conditioning.
- **Control Computer(s).** Used for processing the input signal conditioned data, providing the operator interfaces, and exchanging data between the Data Reduction Programs (which can be hosted either on the Control computer or remote Unix Workstation), and the ATETS II application that resides on a DOS-based PC.
- **Transducers/Sensors.** Used for monitoring engine performance parameters, test cell Instrumentation, and Water Brake instrumentation.
- **Operator Controls.** The following types of controls are included in the C&I system.
  - Levers (Example: for controlling Engine Speed and Water Brake Torque)
  - Control Knobs (Example: for Controlling Np Demand)
  - Panel Buttons and Switches (Example: for testing the Over-speed Engine Function)
  - Vendor Specific Controls (Example: Honeywell Console Kit)

1.4 C&I Real-Time Data Acquisition

1.4.1 This subsystem provides the link between the Operator Console computer and the instrumentation sensors. The Data Acquisition system shall be housed in the Test Cell Control room and controlled via a local computer (PC or Unix based) located in the same room. During testing, a number of channels will be scanned in real time. Typical scan rates are 10 samples per second for each channel. Some channels may have higher scan rate requirements. Section 3.2 provides a detailed listing of the required data acquisition channels and independent requirements for those channels.

1.4.2 The data acquisition system shall be a compact, modular Commercial-Off-The-Shelf (COTS) system from a leading manufacturer, capable of being expanded and upgraded. Industry standard modules and communications interfaces shall be utilized. The system must have the necessary throughput speed to scan, acquire, filter, and display data in real time from all channels simultaneously at the specified rates. Signal conditioning must be included to provide calibrated data acquisition for thermocouples, Resistance Temperature Detectors (RTDs), engine torque meters, and other sensors as necessary. The data acquisition system must be capable of averaging any input signal over a specified time and displaying this average, thus providing digital filtering of the signals when desired.

1.5 C&I Control Computer

The C&I control computer must be able to communicate to the Unix based Workstations located either in the Operator control room, or at a remote location via an Ethernet LAN, which hosts the Data Reduction Programs (DRPs). The Control Computer must also be capable of passing data to the ATETS II computer via RS-232 in response to pneumonic tags sent by ATETS II. Both pilot and co-pilot displays are required, each with the ability to independently display data from pre-determined channels of the data acquisition system. The operator shall have the capability to add or subtract "display data points" of all available channels as required. The display shall be capable of displaying 100 parameters with no degrading of the system. The required screen update rate for all displayed parameters is a minimum of five times per second (5 Hz). The system must also be capable of visually indicating alarm conditions and highlighting out-of-bounds measurements in real-time to provide immediate notification of such conditions to the test cell operators. Where safety conditions are monitored, an audible alarm must also be included, which can be implemented on the controller or with an external device.

1.6 C&I Transducers and Sensors

The C&I transducers and sensors include thermocouples, RTDs, pressure transducers, flow meters, counters or timers, torque meters, vibration transducers, encoders, voltage dividers, engine chip detectors and contact measurement. The requirements for the transducers vary, but each must provide the measurement accuracy specified by the parameter tables provided in Appendix C. In some cases, transducers are integral to the engine or to the facility. In other cases, the transducers or sensors and associated signal conditioning must be purchased from the Engine OEM by the contractor All thermocouples used to measure engine parameters will be provided by CCAD as GFE.

1.7 C&I Controls

1.7.1 Engine speed and Water Brake Torque are normally controlled by the test cell operator. It shall be possible to control these parameters manually, using levers located in the Operator Control Room. In addition, the ability to override and control these parameters automatically via the control software is required. The primary objective of this feature is automatic and rapid chop of the throttle when certain established maximum limits have been exceeded. A secondary objective is the automation of start and test sequences.

1.7.2 The following Controls are required for this system.

1. Water Brake Control Lever(s) to control the Torque applied to the Engine Shaft. NOTE: The Water Brake is not included in the C&I system. However, controlling mechanisms may be included, depending on the Water Brake type.

~~1.~~2. Power Available Spindle (PAS) and Load Demand Spindle (LDS) Levers for Controlling the GE T700.

N1 (Compressor Rotational Speed) and N2 (Power turbine rotational speed) throttle levers for controlling the Honeywell T55L712 engine.

3. ECL throttle lever and N2 set knob for the Honeywell T55GA714A engine.

3.4. Control Knob for controlling the GE T700 Np Demand.

3.5. Panel Buttons and Switches for testing other Engine and Test Cell Functions.

3.6. Vendor Specific Controls. Testing the Honeywell Engines requires a unique Vendor Specific Console which communicates to the Engine Control Unit and provides the Np Demand.

1.8 Software Functional Requirements

1.8.1 A set of overall software functional requirements is given in the following paragraphs. These requirements are envisioned to be provided by a combination of operating system, user applications, test executives, and graphical user interfaces or some subset thereof. It is incumbent on the designer to create a logical and functional partition of these software elements to provide the desired functionality in such a manner that inter-program operation is transparent from the system operator's point-of-view. The intent is to provide a description of the minimal software functionality that is needed. Additional software capability is desired for increased flexibility and maintainability of the system. The preferred method for implementing the software is using a fully functional COTS software package that is easily reconfigurable by CCAD organic support (such as LabView/TestStand or InTouch/Wonderware). Any software code uniquely developed for this application shall be fully documented and shall be delivered with the latest source code and an appropriate development/compilation environment.

1.8.2 The C&I System Software must provide the ability to scan all data acquisition channels, or a selected subset, continuously in real-time at the specified data rates. The software must allow display of different measured parameter subsets on two or more screens simultaneously, for the "pilot" and "copilot" operators. Any subset of the data acquisition channels shall be selectable for display. The parameters shall be displayable in a number of different formats, including numeric, bar graphs, sliders, strip charts and gauges. The display type, location, size, color, scaling, and digital resolution for each parameter must be easily selectable. Software filters, limits and alarms must be selectable for each channel. Calculated values based on formulas, tables and/or multiple data channels must be allowed for calculation and display in real-time, while maintaining all data acquisition sample rates and screen update rates. This includes linearization and/or characterization of sensors when required. The software must be capable of automatically determining when redundant sensors fall outside of a pre-selected correlation tolerance, and providing an alarm indication in such instances. It must also be capable of ignoring a sensor when two or more sensors measuring the same parameter are in significant disagreement.

1.8.3 The software must have the capability of alerting operators when parameters fall outside predetermined limits, usually with color coding or highlighting. Also, when certain chosen parameters fall outside of predetermined limits, the software must be capable of indicating an alarm condition. This can be accomplished with panel mounted alarm annunciators or virtual alarms (on the monitor screen). An audio alarm must also be included for safety conditions. The software must also be capable of evaluating alarm conditions and taking corrective actions, such as retarding the throttle to idle or cutting fuel to the engine. These safety requirements are described in more detail in section 3.3.3.

1.8.4 The software must include calibration and self test modes of operation, and must have modes that are specifically geared toward each type of engine to be tested. The software must also be capable of interfacing with the DRPs via Ethernet and the ATETS II program via RS-232.

1.9 Specific Component Requirements

1.9.1 Vendor Specific Components

The following vendor specific components, when properly installed and integrated into an otherwise compliant test system, provide the required functionality for the C&I System. Alternate system configurations that provide the same functionality for the C&I System can be proposed and will be considered compliant with the solicitation. Either approach is acceptable and meets the requirement for this program.

1. Endevco TFASII Vibration System
    a) Accelerometers: Model 6222S-20 for Engine mounts (2 ea)
        Model 6222S-50 for AGB (1 ea)
        Model CEL-4-128 Water Brake and H2O pump (2 ea)
    b) Charge Converter: Model 2777A-02-25, Gain 2, HP Freq 25Hz. (5 ea)
    c) TFAS II Amplifier System: Model 68222 8-channel Amplifier.
2. FlowDyne IPS Venturi Flow Meter: P/N VP052920-SUF.
3. Honeywell T55GA714A Test Console Package P/N: LTCT30520 Includes:
    Honeywell T55GA714A Operator Console w/ Engine controls and lever.
    Honeywell T55GA714A FADEC (to be mounted in Test Cell near Engine).
    Honeywell T55GA714A Engine Dress Kit P/N LTCT 31100
    Honeywell T55GA714 Torque Meter
4. Honeywell T55L712 Engine Dress Kit P/N: TBD
5. Honeywell Oil Temperature Controller (T55GA714 Engines) P/N LTCT 31486
6. T55GA714A Flight Line Test Set
7. Pile National Connectors (special for G.E.) for the E1 and E3 ECU connectors (See section 3.2.4)

1.9.2 GFE Components

The following Government Furnished Equipment (GFE) is included in the C&I system.

CCAD T55L712 Internal Engine Torque Meter Signal Conditioner (T55GA712 Engines)
All Engine Temperature and Oil Sensors
GE T700 PAS, LDS, and Stage1 Vane Angle encoder engine mounting H/W.
Honeywell T55L712 N1 and N2 encoder engine mounting H/W.

1.10 C&I Parameter Requirements Table

The C&I parameter requirements table is provided in an Excel spreadsheet included as part of the bid solicitation package. This requirements table gives the detailed requirements for each parameter to be measured by the C&I system, including parameter location, performance range, accuracy, engine applicability, sensor/transducer type, and sample rate. Tags are provided for reference to the C&I system diagram.

1.11 C&I System Diagram

The C&I System Diagram is provided in Appendix C. The system diagram includes four separate diagrams of the test cell C&I system as follows:

1. Master diagram showing all C&I required parameters.
2. GE T700 diagram showing C&I parameters required for GE T700 engines only.
3. Honeywell T55L712 diagram showing C&I parameters required for T55L712 only.
4. Honeywell T55GA714A diagram showing C&I parameters required for T55GA714A only.

A parameter tag reference table is provided to define all tags and give a cross-reference to the C&I Parameter Requirements Table.

2. C&I System Characteristics

2.1 Measurement Capabilities

The C&I System must, at a minimum, be capable of measuring the following parameters using Commercial Off the Shelf (COTs) instrumentation and data acquisition equipment:

Engine

Accessory Gear Box: Pressure, Vibration, and Chip Detection
Air Inlet: Temperature & Pressure (PS1, PS1, and T0)
Anti-Ice: Temperature & Pressure
Customer Bleed: Flow, Temperature, & Pressure
Compressor Discharge: Temperature & Pressure (PS3, T3)
Engine RPM: (N1, N2, Ng, Np, Ngg, Npp)
Engine Torque
Engine Static Indicators
Engine Control Levers (PAS, LDS)
Engine NP/N2 Demand Control Pot
Engine Fuel: Flow (Wf), Specific Gravity, Pressure and Temperature
IPS: Airflow (Pressure & Temperature)
Engine Oil Discharge: Pressure & Temperature (EODT, EODP)
Engine Oil Scavenge: Temperatures and Pressures
Power Turbine Inlet: Temp (T4.5, PTT)
Engine Exhaust: Temperature and Pressure (PS9)
Engine Vibration

Facilities

H2O: Flow, Pressure, & Temperature.
Oil Temperature Controller
Air Start Pressure and Control

Water Brake

Water flow rate, temperatures and pressures
Oil pressure & temperature
Torque
Bearing H_2O and oil flow rates, and pressures.

Test Cell

Barometric Pressure
Absolute Humidity
Engine Power supply voltage and current indicators
Lighting Contactor control
Ignition Voltage and Current Indicators

2.1.1 Temperature Measurement

A large number of temperature measurement channels are required for the C&I system, most of them employing thermocouples or RTDs as the sensor. Some important points to consider in developing the required temperature measurement techniques include sensor range and accuracy, dynamic response, noise immunity, resistive losses, cold junction compensation, non-linear characterization, and ruggedized packaging. These characteristics shall be carefully analyzed and optimized for the particular parameter being measured. In some cases, thermocouples will have to be characterized and calibrated in order to achieve the required accuracy. A brief description of the signals to be measured and their required sensors follows:

2.1.1.1 Air Inlet Temperatures (T0) (GE T700 Engines) Range: -40°F to 150°F, Accuracy ±0.5°F. Eight RTD sensors are to be evenly spaced around the circle formed by the Bellmouth screen. Air Inlet temperature is a critical parameter for proper characterization of the engine and correlation testing of the test cell, requiring a great deal of accuracy and long term stability. Careful consideration of error sources such as self-heating and wire resistance must be taken into account to achieve the required accuracy. Response time, defined as time to reach 63% of final temperature when a step change occurs, shall be less than 2 seconds. The typical use of the eight air inlet sensors is to eliminate outliers and average the remaining sensor readings. The data acquisition system must be able to perform calculations in real time with a minimum sample rate of 10 samples per second. These sensors shall be furnished by CCAD as GFE.

2.1.1.2 Air Inlet Temperature (T0) (Honeywell T55 Engines) Range: -40°F to 150°F, Accuracy ±0.5°F. Four RTDs are to be evenly spaced around the circle formed by the Bellmouth screen. A portion of the RTDs allocated for the GE Engine can be used. The RTDs may need characterization before the accuracy specification can be achieved. Response time, defined as time to reach 63% of final temperature when a step change occurs, shall be less than 2 seconds. These sensors shall be furnished by CCAD as GFE

2.1.1.3 Compressor Discharge Temperature (T3) (GE T700 Engines)- Range: 0°F to 1200°F, Accuracy +/-5.4°F. Two custom, dual element Type E thermocouples are used for making this measurement. These sensors shall be furnished by CCAD as GFE.

2.1.1.4 Compressor Discharge Temperature (T3) (Honeywell T55 Engines)-Range: 0°F to 600°F, Accuracy ±5.4°F. Three RTDs shall be furnished by CCAD as GFE.

2.1.1.5 Power Turbine Inlet Temperature (T4.5) (All Engines): 0°F to 2000°F, Accuracy ±5.4°F <1472°F , ±7.2°F >1472°F. A Type K thermocouple is employed in the engine to measure this critical parameter. One data acquisition channel shall be allocated for this sensor.

2.1.1.6 Engine Exhaust Temperature Rake (T9) (All Engines): 0°F to 2000°F, Accuracy ±5.4°F <1472°F , ±7.2°F >1472°F. A thermocouple harness employing six Type K thermocouples, mounted in the engine exhaust flow, is required, providing a single averaged output to the data acquisition system. These sensors are used for diagnostics when troubleshooting the engine.

2.1.1.7 Particle Separator Temperature (GE T700 Engines)- Range: -40°F to 150°F, Accuracy ±0.5°F required. Two RTDs are required for the IPS temperature measurement, and are to be mounted at the inlet of the FlowDyne IPS Venturi Flow meter, a required vendor-specific transducer. Two sensors are used for redundancy and accuracy.

2.1.1.8 Oil Temperatures (GE T700 Engines)- Range: 0°F to 400°F, Accuracy ±0.5°F required Two Type E thermocouples are required to measure the B-Sump Forward oil scavenge temperature and the engine oil discharge temperature (EODT). In addition, 6 Type E Thermocouples and data acquisition channels are recommended for monitoring the other oil scavenge points on the engine during engine diagnostics and troubleshooting.

2.1.1.9 Oil Temperatures (Honeywell T55 Engines)- Range: 0°F to 600°F, Accuracy ±1.8°F below 392°F, ±5.4°F above 392°F. Two Type E thermocouples are required to measure oil scavenge temperatures at the #2 and turbine bearings.

2.1.1.10 Engine Oil Temperature Bulb (Main Oil Pump Discharge Temp.) (Honeywell T55 Engines)- Range: 0°F to 300°F, Accuracy: ±1.8°F. A special nickel RTD is resident in the engine for measuring oil temperature.

2.1.1.11 Engine Oil Out Temperature (Honeywell T55GA714A Engine): Range: 30°F to 510°F, Accuracy ±2°F. A type E thermocouple is required for monitoring the engine oil out temperature, to be located in the facilities oil return line. This sensor is used to identify a safety alarm condition.

2.1.1.12 Oil Temperature Controller Temperatures (Honeywell T55GA714A Engine)- Range: 30°F to 510°F, Accuracy ±3°F. 3 RTDs appropriate for measuring oil temperature shall be employed for oil cooler inlet, outlet and an oil calibration loop on the LTCT 31486 oil temperature controller required

2.1.1.13 Fuel Temperature (All Engines): Range: -100°F to 200°F, Accuracy ±0.5°F required. Two Type E thermocouples are required for measuring the fuel temperature near each of the two fuel flow meters in the facility.

2.1.1.14 Engine Anti-ice Temperature (GE T700 Engines): Range: 30°F to 510°F, Accuracy ±2°F required. A Type E or Type K thermocouple is required for making this measurement. The sensor is to be mounted at the applicable port on the Engine Bellmouth. This sensor is used for engine troubleshooting.

2.1.1.15 Customer Bleed Air Temperature (GE T700 Engines): Range: 500°F to 800°F, Accuracy ±5.4°F required. A Type E thermocouple is required for mounting on the customer bleed engine compressor port. This sensor is used for engine troubleshooting.

2.1.1.16 Water Brake Strain Gauge Temperature (All Engines): Range: 30°F to 950°F, Accuracy ±5°F required. A Type E thermocouple is required to monitor the water brake strain gauge temperature. A thermocouple sensor is recommended due to the location of the sensor and its possible exposure to water.

2.1.1.17 Water Brake Water Temperatures (All Engines): Range: 30°F to 210°F, Accuracy ±3°F required. Two Type E thermocouples are required to measure water in and out temperatures. Thermocouple sensors are recommended due to the location of the sensors and their possible exposure to water.

2.1.1.18 Water Brake Oil Scavenge Temperatures (All Engines): Range: 0°F to 600°F, Accuracy ±3.0°F required. Three Type E thermocouples are dedicated to rear and forward bearing oil scavenge temperature measurements on the water brake. Thermocouple sensors are required due to the location of the sensors and their possible exposure to water.

2.1.1.19 Cooling Tower Basin Water Temperature (All Engines): Range: 30°F to 210°F, Accuracy ±3°F required. A Type E thermocouple is recommended to monitor the cooling tower basin water temperature for safety and diagnostic information. A thermocouple sensor is recommended due to the location of the sensor and its possible exposure to water.

2.1.1.20 Hydraulic Start System Temperature (All Engines): Range: 30°F to 510°F, Accuracy ±3°F required. An RTD shall be provided to monitor the Hydraulic Start System temperature for safety and diagnostic purposes.

2.1.1.21 Spare Thermocouple Channels: Sixteen channels of spare thermocouple data acquisition, signal conditioning, and harness routing shall be supplied capable of accepting type K or type E thermocouples.

2.1.1.22 Spare RTD Channels: Sixteen channels of spare RTD data acquisition, signal conditioning, and harness routing shall be supplied, capable of accepting RTD sensors.

2.1.2 Pressure Measurements

Pressure measurements for measuring air, oil, water, and fuel are required as part of this acquisition specification. When possible, the sensors are to be located in an enclosure in the test cell, and connected to the engine's "pressure ports" via pneumatic tubing and "quick-disconnect" fittings. The use of digital pressure transmitters is required when accurate measurements are required, provided that acquisition speed requirements can be met. In addition to providing scaled data back to the C&I system, using digital pressure transmitters reduces the overall number of data acquisition channels required by the C&I system. The following paragraphs detail the pressure transducers and measurements required for supporting the C&I system. The transducers are divided into four categories; Air, Fuel, Oil, and Water.

2.1.2.1 Air Pressure Sensors

2.1.2.1.1 Air Inlet Pressure (PS0) (All Engines): Range: 0-10" H_2O, Accuracy ±0.1% FS value (GE Specification). The T700 DMWR specifies using 4 static baskets, each with 4 sensor inputs for measuring the Bellmouth Static Pressure. The Honeywell T55 Engine Specification only requires the use of 1 static basket. These pressure ports are located at the front end of the bellmouth and are used for determining the inlet air pressure. This reading in conjunction with the Bellmouth Throat Static Pressure is used in calculating the Engine Mass Air Flow (an important parameter in determining the engine efficiency).

2.1.2.1.2 Bellmouth Throat Static Pressure (PS1) (All Engines): Range: 0-5 psig, Accuracy ±0.1% FS value (GE Specification). The T700 DMWR specifies the use of 8 sensors spaced every 45 degrees around the bellmouth. The Honeywell DMWR specifies the requirement for 4 sensors for the T55L712 engine and 3 sensors for the T55GA714A engine.

2.1.2.1.3 Compressor Discharge Pressure (PS3) (All Engines): Range: 0-300 psig, Accuracy ±0.1% FS value (GE Specification). A pressure port is located on the compressor for measuring the air pressure as it leaves this stage of the engine. Since this transducer is used across all three engines with varying ranges, it is required that a pressure transmitter with a programmable range setting be used. A transducer with a 0-300 psig range will accommodate all three engine types.

2.1.2.1.4 P3 Boroscope Pressure (PS3-X). (GE Engines)

2.1.2.1.5 Combustor Inlet Total Pressure (T55L712 Engines)

2.1.2.1.6 Compressor Discharge Pressure #2 (PS3) (T55GA714A Engines): Range: 0-300psig, Accuracy ±0.1% FS value (GE Specification). This is a secondary port that is used for measuring the air pressure as it leaves the compressor stage of the engine. Since this transducer is used across all three engines with varying ranges, it is required that a pressure transmitter with a programmable range setting be used. An XDCR with a 0-300psig range will accommodate all three engine types.

2.1.2.1.7 Exhaust Static Pressure (PS9) (GE Engines): Range: 0-10" H_2O, Accuracy ±0.1% FS value (GE Specification). The T700 DMWR calls out the use of 2 transducers for calculating this value. The two pressure ports are located on the Engine Turbine.

2.1.2.1.8 IPS "Particle Separator" (GE Engines): 0-10" H_2O at inlet, and 0-60" H_2O at throat, Accuracy +0.1% FS value (GE Specification). The GE Engines divert a portion of the inlet airflow to the particle separator to filter out impurities in the air entering the engine. It is important however to calculate this airflow so that it can be subtracted from the total inlet airflow and provide the true airflow entering the engine. To calculate the flow, two pressure measurements are recorded, along with a temperature reading taken at the venturi inlet. The pressure measurements are taken at the venturi flow meter inlet and throat. The delta pressure is then used in conjunction with the temperature and flow chart to calculate the mass airflow. The T700 DMWR specifies using thee redundant ports at the inlet and two at the throat for calculating the pressure readings.

2.1.2.1.9 Customer Bleed Pressure (GE Engines): Range: 150-250psig, Accuracy ±2%. This port is located on the engine compressor and provides auxiliary air pressure to the cabin. This parameter is useful for troubleshooting engine problems.

2.1.2.1.10 Water Brake Air Supply Pressure (All Engines): Range: 0-300 psig, Accuracy ±2%. This sensor monitors the air pressure going to the water brake.

2.1.2.1.11 Air Start Pressure (All Engines): Range: 0-50 psig, Accuracy +/-2%. This transducer monitors the air pressure going to the Engine Air Starter.

2.1.2.1.12 Barometric Pressure (All Engines): Range: 27-33" Hg, Accuracy ±0.006 "Hg. This sensor is mounted in the Test Cell and is used in calculating the Engine Mass Airflow.

2.1.2.2 Fuel Pressure Sensors

2.1.2.2.1 Fuel Inlet Pressure (All Engines): Range: 0-100 psig, Accuracy ±2%. This pressure port is located at the Engine fuel inlet.

2.1.2.2.2 Secondary Fuel Inlet Pressure (T55L712 Engines): Range: 0 to -30" Hg, Accuracy +2%. Secondary port on T55L712 Engines used for monitoring engine fuel pressure. This port produces a negative pressure.

2.1.2.2.3 Fuel Boost Pressure (GE Engines): Range: 0-200 psig, Accuracy ±2%. This pressure port is located on the Accessory Gear Box.

2.1.2.2.4 Fuel Control Pump Pressure (T55 Engines): Range: 0-1000 psig, Accuracy ±2%. This sensor port is located on the engine manifold downstream from the fuel pump.

2.1.2.2.5 Facilities Fuel Filter Pressure – Upstream (All Engines): Range: 0-100 psig, Accuracy ±2%. This sensor port is located on the Test Cell Fuel piping upstream from the fuel flow meters and facilities fuel filter.

2.1.2.3 Oil Pressure Sensors

2.1.2.3.1 Engine Oil Discharge Pressure (EODP) (All Engines): Range: 0-200 psig, Accuracy ±2%.

2.1.2.3.2 Gear Box Pressure (T55 Engines): Range: -30 - +60 psig for T55L712 Engines, 0-10psig for T55GA714A Engines, Accuracy ±2%. This sensor is located on the Engine Gearbox.

2.1.2.3.3 Rear Bearing Oil Inlet Pressure (T55 Engines): Range: 0-100 psig, Accuracy +2%.

2.1.2.3.4 Power Turbine Bearing Oil Scavenge Negative Pressure (T55L712 Engines)

2.1.2.3.5 Bearing 4&5 Oil Scavenge Negative Pressure (T55GA714A Engines): Range: 0 to -15 psig, Accuracy ±2%. Note this is a negative pressure.

2.1.2.3.6 B-Sump Scavenge Pressure (GE Engines): Range: 0-10 psig, Accuracy ±2%. This port is part of the Engine Lube System. This is not a critical parameter, but is useful for troubleshooting engine problems.

2.1.2.3.7 Water Brake Lube Oil Supply pressure (All Engines): 0-50 psig, Accuracy ±2%. This transducer is located downstream from the facilities water brake bearing lube oil supply and is used in conjunction with a flow meter to monitor the status of the oil flow and pressure entering the water brake.

2.1.2.3.8 Facility Lube Oil Level Pressure (All Engines): Range: 0-60" H_2O, Accuracy ±2%. This transducer is used for monitoring the facilities oil reservoir level.

2.1.2.3.9 Facility Lube Oil Pressure (All Engines): Range: -25 - +25" Hg. Accuracy ±0.5"Hg. This transducer is used for monitoring the oil pressure in the facilities lines running to the engine.

2.1.2.4 Water Pressure Sensors

2.1.2.4.1 Water Brake Pump Pressure (All Engines): Range: 0-200 psig, Accuracy ±2%. This sensor is located on the Water Brake pump outlet. It measures the water pressure leaving the pump supplying water to the water brake.

2.1.2.4.2 Water Brake Bearing Pressure (All Engines): Range: 0-300 psig, Accuracy, ±2%. This sensor is used in conjunction with a turbine flow meter to monitor the water pressure going to the Water Brake bearings.

2.1.2.4.3 Water Brake "In" Water Pressure (All Engines): Range: -30 -150 psig, Accuracy ±2%. This sensor is located on the water brake. It measures the water pressure entering the water brake.

2.1.2.4.4 Water Brake "Out" Water Pressure (All Engines): Range: 0-160 psig, Accuracy ±2%. This sensor is located on the water brake. It measures the water pressure leaving the water brake.

2.1.2.4.5 Cold Water Level Pressure (All Engines): Range: 0-60" H_2O, Accuracy ±2%. This sensor is used for monitoring the cold water level in the facility.

2.1.3 Flow Measurements

The C&I system depends on various flow measurements for Engine efficiency testing as well as for monitoring test cell safety conditions. Turbine and/or paddlewheel meters are required depending on accuracy requirements. The following paragraphs provide the range and accuracy details for the flow meters used in the C&I system.

2.1.3.1 Fuel Mass Flow Measurment (Wf) (All Engines): Accuracy ±0.5%. One in-line turbine flow meter is required for this measurement as per the T700 DMWR. A second redundant coriolis flow meter is also required. The coriolis measurement technique eliminates the need for specific gravity measurement, and shall have higher accuracy. The coriolis meter must maintain the required accuracy at the sample rate of 10 Hz (response time must be <= 0.1 mS). The suggested model is the Foxboro model CFT50. The flow rate obtained from the turbine flow meter is used in conjunction with the fuel specific gravity measurements, which must be made with a hydrometer (0.002 resolution), to calculate the fuel mass flow going to the engine. The meters are located in the Test Cell Fuel piping and shall be sized to support a flow range from 25 lb/hr to 2500 lb/hr (turndown ratio of 100:1). The C&I system must be capable of obtaining a linearized result for fuel mass flow at the specified data acquisition rate of 10 samples per second.

2.1.3.2 IPS "Particle Separator" Mass Flow (GE Engines): For measuring the mass airflow through the particle separator, a Flowdyne Venturi Flow Meter, P/N VP052920-SUF is required. In addition to providing the flow meter, the vendor shall also be responsible for providing the IPS exhaust line from the engine to the flow meter.

2.1.3.3 Customer Bleed Raw Flow (GE Engines): Accuracy +2%. The flow meter is connected to a port on the engine compressor and shall be sized to support a flow of 5-50lb/hr.

2.1.3.4 Facility Water Brake Water Flow Rate: Accuracy ±2%. This flow is monitored to insure that sufficient water is flowing into the water brake from the facilities cooling basin. The meter is located in the Test Cell Water Brake facilities piping and should be sized to support a flow range from 0 to 120gpm. Approximate facilities pipe diameter is 3".

2.1.3.5 Water Brake Bearing H_2O Flow Rate: Accuracy ±2%. This flow is monitored to insure that sufficient water is flowing into the water brake bearing from the facilities cooling basin. The meter is located in the Water Brake plumbing and shall be sized to support a flow range from 15 to 20 gpm. Facilities pipe diameter is ½".

2.1.3.6 Water Brake Bearing Oil Flow Rate: Suggested transducer output range: 0-2000 Hz, Accuracy ±2%. This flow is monitored to insure that sufficient oil is flowing into the water brake bearing from the facilities water brake lube oil supply. The meter is located in the water brake Oil lube piping. Facilities pipe diameter is ¼".

2.1.3.7 Water Brake Air Flow Rate: Suggested transducer output range: 0-2000 Hz, Accuracy ±2%. This flow is monitored to insure that sufficient air is flowing into the water brake from the facilities CDA supply. The meter is located in the Water Brake pneumatic tubing. Approximate facilities pipe diameter is ¼".

2.1.3.8 Engine Lube Oil Flow Rate: Suggested transducer output range: 0-2000 Hz, Accuracy ±2%. This flow is monitored to insure that sufficient oil is flowing into the Engine Lube System from the facilities lube oil supply. The meter is located in the facilities oil lube plumbing. Facilities pipe diameter is ½".

2.1.4 RPM Measurements

2.1.4.1 RPM measurement is critical for engine test, and several important aspects must be considered. A periodic signal is provided whose frequency is proportional to the rotor RPM. The different engines have different transducer frequencies at 100% rotational speed, as shown in table 3-1:

Engine	Parameter	Percent Speed	Rotational Speed	Transducer Freq.
T700	Ng	100%	44700 RPM	2135.7 Hz
T700	Np	100%	20900 RPM	1393.3 Hz
T55L712	N1	100%	18720 RPM	70 Hz
T55L712	N2	100%	15334 RPM	70 Hz
T55GA714A	NGG	100%	18720 RPM	2787 Hz
T55GA714A	NPT	100%	15334 RPM	2816 Hz

Table 3-1 – Engine Rotational Speeds and Transducer Frequencies at 100% Speed

2.1.4.2 In order to sample the rotational speed parameters at a required 10 samples per second rate, a period measurement of one-half, one, or a small number of cycles is required. The period shall then be converted to frequency and the calculated values of RPM and % speed shall be reported. The basic accuracy for the measurements is ±0.2%. A COTS counter/timer data acquisition component may be employed.

2.1.4.3 An important consideration for the RPM measurements is software filtering/averaging. The data acquisition system must be capable of performing averaging/filtering, and reporting the result as the RPM in real time. RPM "jitter" is a common problem in testing engines, especially when utilizing a Water Brake load. Excessive jitter can make snap shots of engine performance inaccurate. However, filtering that excessively reduces fluctuation and change will not be acceptable to Quality Assurance. Flexibility in filtering and/or averaging techniques is therefore required.

2.1.4.4 The data acquisition system can utilize two channels for RPM measurement which support the requirements for all three engine types, or it may use up to six channels, one for each engine specific rpm measurement, if needed to meet the different frequency requirements. In addition, two spare channels are required for future expansion.

2.1.5 Torque Measurement

2.1.5.1 Engine torque is measured internally in the engine, as well as on the water brake load. For the GE T700 engines and the Honeywell T55GA714A, an output voltage of 0-8VDC must be measured to an accuracy of ±0.05% for internal engine torque. This correlates to approximately 0-9600in-lbs for the GE T700 engines and 0-24,000 in-lbs for the Honeywell T55-GA-714A engines. For the GE engines an external torque stabilizer is required to reduce torque oscillations. This stabilizer is a CCAD GFE item.

2.1.5.2 For the T55L712 engine internal torque, a special power supply/signal conditioner circuit is required, and will be supplied by CCAD. The resulting output is a 0 to 80 millivolt DC nonlinear signal, as graphed in DMWR 55-2840-254 Figure 7-4. The output of the signal conditioning circuit must be properly calibrated and characterized, as described in the DMWR. A data acquisition channel shall also be provided to measure the power supply voltage for the T55L712 strain gauge signal conditioning circuit, which has a range of 0 to 500 millivolts AC. This measurement is for diagnostic purposes.

2.1.5.3 The exact method for measuring water brake torque is to be determined. One or more channels must be dedicated to load torque measurement as required, with the range of torque values being 0 to 2000 lb-ft and the required accuracy being ±1.5 lb-ft.

2.1.6 Encoder Measurement

2.1.6.1 The C&I system includes several encoders for testing the GE T700 (3 encoders), Honeywell T55L712 (2 encoders), and Honeywell T55GA714A (1 encoder) engines.

2.1.6.2 GE T700 Encoders. Range: 0-360°, with a minimum of 900 pulses/revolution, Incremental Encoder. The GE engine requires three encoders for monitoring the position of the Power Available Spindle (PAS) (0° to 130°), Load Demand Spindle (LDS) (0° to 130°), and the Stage 1 Vane Angle position (-10° to 40°). These encoders are mounted on custom manufactured brackets that attach to the engine. It is required that the encoders be identical to those presently used at CCAD, or a form-fit-functional replacement. The encoders used in existing CCAD test cells are DRC (now GSI Lumonics) Incremental Encoders.

2.1.6.3 Honeywell T55L712 Encoders. Range: 0-360°, with a minimum 900 pulses/revolution, Incremental Encoder. The C&I system requires one encoder mounted to the existing CCAD interface bracket for monitoring the Power Lever Position (0-160deg). A second encoder for monitoring the N2 throttle position is preferred for diagnostic testing.

2.1.6.4 Honeywell T55GA714A Encoders. Range: 0-360°, with a minimum 900 pulses/revolution, Incremental Encoder. The C&I system requires one encoder mounted to a CCAD interface bracket for monitoring the Engine Control Lever Position (0-90deg).

2.1.6.5 In addition to the encoders, the C&I system requires a data acquisition card capable of monitoring both 2X and 4X quadrature counting. Separate channels shall be allocated for each encoder input for the three engine types.

2.1.7 Vibration Measurement

2.1.7.1 The required method for acquiring vibration measurements as part of the C&I system is to procure the same measurement hardware used in the existing test cells. An alternate system may be proposed and considered which meets the requirements and offers enhancements to those existing. The current hardware used is an Endevco TFAS II Vibration system, which is comprised of the following hardware:

a) Accelerometers: Model 6222S-20 for Engine mounts (2 ea)
Model 6222S-50 for Accessory Gear Box (AGB) (1ea)
Model CEL-4-128 Water Brake and Facilities Water Pump (2 ea)

b) Charge Converter: Model 2777-02-25; Gain: 2, HP Freq: 25Hz. (1 per Accelerometer).

c) TFAS II Amplifier System: Model 68222 8-Channel Computer-Controlled Digital Tracking Filter Amplifier.

2.1.7.2 The accelerometers are to mount directly to the Engine Accessory Gear Box (AGB) and Turbine. The outputs of the accelerometers are connected to the 2777 Charge Converters, which are mounted to the engine hoist. For testing GE engines, the acceleration output of the converter is used, whereas on the Honeywell engines, the velocity output of the converter is used. The output of the charge converters are routed to the operator control room to the TFAS II Amplifier System.

2.1.7.3 The TFAS II Amplifier System is contained in a 19" rack mountable chassis and is computer controlled via IEEE-488. There are 3 analog outputs for each input channel (Amplitude, Frequency, and Phase). These analog outputs are then fed into the C&I system for determining pass/fail criteria.

2.1.7.4 An alternate vibration monitoring system, which incorporates the technical requirements as stated, will be considered for adoption. The system must be able to include water brake system vibration and provide for comparison of all inputs in real time.

2.1.8 Chip Detectors

2.1.8.1 Three chip detectors must be monitored by the data acquisition system (gearbox, power turbine oil scavenge and No. 2 bearing oil scavenge). The magnetic field of a chip detector is designed to capture debris particles which can bridge a gap between two electrodes. This bridging acts as a switch closure for an alarm circuit or "chip" light.

A typical circuit employing a chip detector is shown below.

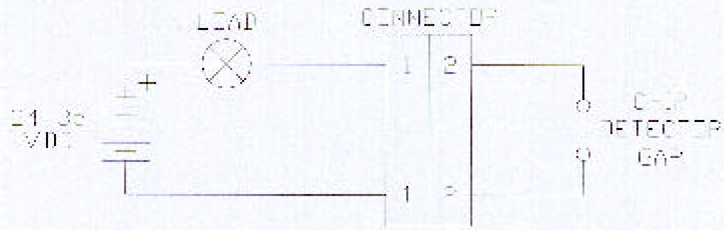

Figure 3.2-1. Typical Chip Detector Circuit

2.1.8.2 The load is normally a cockpit indicator lamp with a typical resistance of 500 to 1500 ohms. The signal conditioning for monitoring the chip detectors shall include 28 Vdc excitation and a 28 volt panel mount light on the test cell operator console, or an equivalent load and an alarm indicator light. Chip detector voltage or current shall be monitored by the data acquisition system. In addition to the three required chip detector channels, one spare chip detector channel shall be provided to include the required power and signal conditioning circuit.

2.1.9 Engine Static Indicators.

The C&I System requires the ability to monitor static dc signals coming from the Engine. These are typically 0-15vdc signals coming from the engine ECU. The "ON/OFF" status of these signals needs to be visually available to the test cell operators. The following is a list of signals in this category.

Oil Filter Bypass Indicator (GE Engines): 0-15 vdc.

Fuel Filter Bypass Indicator (GE Engines): 0-15 vdc

Anti-Icing Bleed and Start Valve Indicator (GE Engines): 0-15 vdc

Torque Match Input Indicator (GE Engines): 0-15 vdc.

2.1.10 Absolute Humidity

Absolute humidity in the test cell must be measured. Range: 0 to 200 grains/lb, Accuracy +2%. This can be accomplished by using a dew cell hygrometer with an RTD temperature output, a humidity/dewpoint transmitter with an RS-232 or other communications interface, or a chilled mirror hygrometer. The mixing ratio is the calculated parameter that is required, with units of "grains per pound".

2.1.11 Voltage and Current Measurement

2.1.11.1 The following ranges of voltage and current measurement are needed.

400Hz Power Supply Voltage (All Engines): 0-30 vdc

400Hz Power Supply Current (All Engines): 0-50 mA

Ignition voltage indicator (All Engines): 0-125 V

Ignition current indicator (All Engines): 0-3 A

2.1.11.2 The Honeywell T55L712 Engine requires the use of a special signal conditioning module that includes a GFE engine power supply for measuring the Engine Torque. For troubleshooting and diagnostic purposes, it is required that the following signals be monitored by the C&I system.

Torque Meter Power Supply Voltage: 0-500 mVAC.
Torque Meter Power Supply Current: 0-100 mA
Torque Meter Power Supply Output Frequency: 0-2000 Hz

2.1.11.3 In addition to these measurements, at least 16 spare channels for voltage, 8 spare channels for current, and 8 spare channels for frequency shall be provided.

2.1.12 Alarm Annunciators

2.1.12.1 The system shall include alarm annunciators for indicating when certain parameters fall outside of predetermined, configurable safety limits. The annunciators can be implemented with panel mounted lights or with virtual alarms (on the monitor screens). An audio alarm must accompany the alarm condition. The audio alarm shall be ergonomically balanced such that it makes the operators aware of the condition, but does not present an annoyance or irritation. Typical alarm annunciators are as follows:

Water Brake:

- Low Water Brake Pressure
- Low Water Level
- Low Bearing Water Flow
- High Water Brake Temperature
- Low Brake Oil Pressure
- Low Brake Oil Flow

Engine:

- Low Engine Oil Inlet Pressure
- Low Engine Oil Filter Out Pressure
- Low Engine Oil Level
- High Engine Oil Temperature
- Low Fuel Pressure
- Anti-Icing Pressure
- High Cell Oil Temperature
- Chip Detector #1
- Chip Detector #2
- Chip Detector #3
- T700 Fuel Bypass
- T700 Oil Filter Bypass
- T700 Low Fuel Boost Pressure
- T700 A/I Valve

2.1.12.2 In addition to the above annunciators, the system shall have the capacity for additional annunciators (at least 16), such that they could be easily inserted into C&I system to satisfy future requirements.

2.1.12.3 Annunciators shall blink until acknowledged by the operator, and shall stay lit thereafter until cleared. Clearing the annunciators shall be password protected. An annunciator test feature (button) shall be included such that when the test is executed, all annunciators are caused to blink.

2.1.13 Max Values

The C&I system must have the ability to store the maximum acquired reading and duration for a particular set of parameters during test, which can then be easily retrieved and displayed by a Quality Assurance inspector. These max values shall only be clearable when a key is inserted into an enabling key switch, available on the console, and which cannot be overridden by the operators. Testing of another engine shall not be possible until the max values are cleared by the Quality Assurance inspector (who holds the key). The parameters typically chosen for max values are:

PTIT/EGT/MGT

Load (Water Brake Torque)

Compressor Speed

Power Turbine Speed

2.2 Control and Stimulus Capabilities

The C&I system must provide the capability to control the Engine speed and water brake Torque manually using levers located in the Operator Control Room. In addition, automatic control via the software for stability must be included. Control levers shall have no delay or hysteresis between movement of the lever and movement of the corresponding drive mechanism.

The following Controls are required for this system.

1. PAS and LDS Levers for controlling the GE T700 Engine.
~~1.~~2. N1 and N2 Throttle Levers for controlling the Honeywell T55L712 Engine.
~~1.~~3. ECL for controlling the Honeywell T55GA714A Engine.
~~1.~~4. Load Control Levers for controlling the water brake Torque.
~~1.~~5. Control Knob for controlling the NP Demand.
~~1.~~6. Control Knob for controlling N2 Demand (T55 GA714A).
~~1.~~7. Panel Buttons and Switches for testing other Engine and Test Cell Functions.
~~1.~~8. Discrete Control Signal Outputs.

2.2.1 GE T700 Engine PAS and LDS Levers.

Two levers are required for controlling these spindles. It shall be left to the Test Cell contractor to determine the best means of interfacing the control levers to the hardware linkage provided by CCAD. In designing the interface, human factors and software override capabilities shall be considered.

2.2.2 Honeywell T55L712 Throttle and Power Turbine Speed Control

A control lever is required for controlling N1 speed of the T55L712 engine. A second lever is required for power turbine (N2) speed control. It shall be left to the Test Cell Contractor to determine the best means of interfacing the control levers to the hardware linkage provided by CCAD. In designing the interface, human factors and software override capabilities shall be considered.

2.2.3 Honeywell T55GA714A Engine Control Lever and N2 Knob.

This ECL is part of the Vendor Specific required components, as is the N2 Demand Knob. They are included as part of the Honeywell Operator Console package. The test cell contractor needs to verify with Honeywell whether or not the linkage and engine mounting hardware is included. If not, the test cell contractor shall be responsible for providing the interconnecting hardware.

2.2.4 Load Control Levers

Two Water Brake Control Lever(s) are required to control the Torque applied to the Engine Shaft. One lever shall control the water pressure entering the water brake, and the second controls the water leaving the water brake. These levers are to be located on the control console in the operator control room.

2.2.5 NP Demand Control Knob (GET700)

The NP Demand Control Knob is comprised of a 10-turn potentiometer with a 10% tap. The potentiometer range is ±15vdc.

2.2.6 Panel Buttons and Switches

2.2.6.1 The Operator console requires a bank of buttons/switches that allows the operator to control test cell and engine functions. A minimum of 64 are required, with a suggested minimum contact rating of 1 amp. Below is a list of example control signals requiring manual control via button/switch that shall be included:

Overspeed Test Switch -2 ea- (GE and T55GA714A Engines):

Air Start ON/OFF Control (All Engines):

Ignition ON/OFF Control (All Engines):

400Hz Power Supply ON/OFF Control (All Engines):

Engine Fuel Flow Valve Cutoff Switch (All Engines):

Test Cell Lighting Contactors – minimum of 6 ea.

Chip Detector Power

Alarm Test

Alarm Acknowledge

Manual Timer

Emergency Fire Suppression

2.2.6.2 Engine start and emergency fire suppression functions shall be protected by dual enabling key switches. The key switches shall also have at least one additional set of contacts (normally closed) to allow adjacent test cell start functions to be locked out when the keys are in the enable position.

2.3 Control Signal Outputs

The system shall provide a minimum of 8 control voltage outputs (0-10V) that can be programmed to provide PID control based on any variable measured by the C&I system, with a loop cycle time as short as 10 mSec. These control signals are intended to provide system flexibility for future expansion, or for solving open loop control problems that might present themselves. 4-20 ma and the PID software shall be supported with an autotune program, like ExperTune's Products. Each PID loop shall allow for characterizer for the process across the entire range (mutli PID's for the process).

2.4 Hardware and Software Filters

2.4.1 The C&I System must have the ability to implement a variety of hardware and software filters. The hardware filtering shall be included as part of the signal conditioning for each channel. A typical hardware filter shall be set to an anti-aliasing 3-pole low-pass frequency of 5 Hz, but other filter frequencies shall be available. Suggested filters are provided in the parameter table in Appendix C.

2.4.2 The ability to implement software filters is required, including the ability to use running averages and box-car averaging. An example of a typical software averaging algorithm is using 70% of the running average of a signal and 30% of the latest reading to produce the next displayed value. Other examples of desirable software filters include digital Butterworth and First Order Lag filtering algorithms.

2.5 Special Connections

2.5.1 Special connectors are required for interfacing to the G.E. T700 Engines. The "E1" connector, located on the ECU, includes contacts for T4.5, overspeed test switch, NP demand, engine torque, torque match input and 400 Hz power supply monitoring. The mating connector for E1 is made especially for General Electric by Pile National, P/N BF8-1216-24SV-Y89. This connector may need to be purchased from G.E and will likely have long lead times. It is important to note that different versions of the engine may have different E1 pin-out definitions. The C&I system must have the capability of adapting to a number of different pin-out combinations for E1 through switching, conversion cables, or other means.

2.5.2 Similarly, the mate for the E3 connector, Pile National P/N BF8-1216-24SV06-Y70, is also especially made for G.E. This connector contains contacts for items such as ignition voltage and current, chip detectors, oil and fuel filter bypass switches, NP and NG tachometer outputs, and other signals.

3. Design and Construction

3.1 Standards

The C&I system shall utilize industry standards for instrumentation, interfaces, computers and software to the maximum extent possible. ISA standards and conventions shall be followed, especially with respect to the referencing of data acquisition channels and sensors.

3.2 Modularity and Interchangeability

The C&I system shall be modular in nature, allowing easy replacement and expansion of data acquisition modules, signal conditioning modules, sensor/transducers and control computers. Proprietary interfaces and architectures are discouraged and require specific approval by CCAD. Open architectures which allow integration and substitution of hardware from multiple instrumentation vendors are preferred. A design which reduces overall system footprint is also desirable. Each control room supports two test cells requiring typically 2-4 operators on-hand during engine testing. It is required that the data acquisition hardware and harness terminations be installed in no more than two 19" wide racks, with a maximum height of 6 ft. Operator consoles shall be no larger than 7 ft long and 28 inches deep (excluding work surface depth), with a desktop worksurface on the front of the consoles having a maximum depth of 18 inches.

3.3 Safety

3.3.1 The Test Cell Control and Instrumentation system must be capable of monitoring various discrete input signals to provide hardware safety interlock protection for control outputs to the Engines. Below is a list of the control outputs that require hardware interlock protection and their associated sensor inputs.

1. Engine speed, max throttle operator entry, and air-starter ignition relay (HS0805) controls: If any of the below conditions exist, or occur during testing,

    a. the Engine throttle speed automatically retards to idle,

    ~~a.~~b. the operator is prevented from entering the max throttle value,

    ~~a.~~c. starter ignition relay is disabled:

    Sensor Input Interlock Condition:

    1. Water Brake Bearing flow rate decreases below min level

    ~~1.~~2. Water Brake Supply Pump Pressure decreases below min level.

    ~~1.~~3. Gearbox Vibration sensor exceeds max limit

    ~~1.~~4. Upper Power Turbine Vibration sensor exceeds max limit.

    ~~1.~~5. Lower Power Turbine Vibration sensor exceeds max limit.

    ~~1.~~6. Water Brake Vibration sensor exceeds max limit.

    ~~1.~~7. Engine Lube Oil Pressure decreases below min limit & NG Speed is greater than 52%

~~1.~~8. NP (N2) Engine Speed exceeds max Limit

~~1.~~9. NG (N1) Engine Speed exceeds max limit

~~1.~~10. Operator depresses the **ESD** Momentary Switch

In addition, if the Operator Depresses the ESD Momentary Switch, the Fuel Valves controlling the engine inlet fuel (FV0022 and FV0022A) shall be shut off.

3.3.2 Once activated, the Interlock state shall remain until the problem is resolved and the software issues a "Reset" command via operator input.

3.3.3 In addition, the C&I system shall provide the following capabilities:

1. Continuous parameter limit checking of engine and test cell sensors.
~~1.~~2. Provide system actions resulting from limit alarms and automatically record all limit messages.
~~1.~~3. Provide a security system to prevent unauthorized access to operation, data, or system configuration.

3.4 Human Factors

The following ergonomic factors shall be addressed by the C&I system:

1. The C&I System shall provide an easy to use Graphical User Interface (GUI) for both the "Pilot" and "Co-Pilot" Operators.
~~1.~~2. Annunciators shall be large enough so that they are highly visible such that the operators can easily ascertain the nature of the alarm. As a goal, the audible alarm shall be evident but shall not be irritating.
~~1.~~3. The system shall have a small enough footprint that visitors to the test cell can easily pass through and there shall be ample work space for the operators.
~~1.~~4. Lighted buttons are preferred for use with console contact switches, providing a clear indication of the state of the switch.

4. Operation and Maintenance

4.1 Reliability

This supportability requirement includes all failures in which are critical to the proper operation and diagnostic capability of the C&I System. Under normal use and operation the C&I System shall not fail within 1500 hours of operation with a statistical certainty of 95%.

4.2 Service and Maintainability

4.2.1 Service and maintainability are important factors to be considered in the C&I design. The objective is to ensure that maintenance provisions are addressed during the design phase.

4.2.2 The C&I System shall be designed and constructed using standard hardware that will meet the following conditions.

1. Procured hardware shall, whenever possible, be standard off the shelf parts which can be replaced with short lead times (1-2 weeks).
2. Safety, Functionality, Reliability, Replacement Lead times and Cost are factors that shall be considered when purchasing hardware.
3. Equipment design shall facilitate rapid, positive fault detection and isolation of defective items.
4. All wiring, components and terminations shall be appropriately labeled, and the labeling shall match the system documentation.

5. Standard parts shall be used whenever practical. Components shall be replaceable as module packages, and configured for rapid removal and replacement.
6. Equipment requiring periodic calibration and adjustment must be readily accessible without disassembly.
7. Guides, tracks, or stops shall be provided as necessary to facilitate handling and prevent damage to equipment or injury to personnel.
8. Sharp edges and corners that present a personnel safety hazard or potential damage to clothing or equipment shall be suitably protected or rounded.
9. Equipment shall have integral lighting in maintenance areas, which would otherwise be poorly illuminated.

4.3 Supportability

All C&I hardware and software components shall be purchased from reputable, leading vendors in test and measurement instrumentation. Components chosen shall be expected to have long term support by the OEM. Vendors who have representation in the Corpus Christi area are preferred. The following additional C&I system supportability features are required:

1. Automatic self-tests during startup.
2. Diagnostic utilities for hardware troubleshooting
3. Modular construction for easy replacement of component parts.
4. Built-in utilities for simulating data for use in troubleshooting.
5. Complete documentation and drawings for all system hardware and software components, including test cell wiring diagrams, schematics and parts lists.

4.4 Calibration

4.4.1 All measuring instruments/devices/standards associated with the C&I system must be ordered with a calibration certificate. Periodic Calibration is required as per the OEM recommended calibration cycle. Calibration shall be compliant with ANSI/NCSL Z540-1. The test cell contractor shall provide a compliant calibration procedure for the entire C&I system.

4.4.2 Software shall be provided to facilitate calibration of all data acquisition channels. As a minimum, calibration limits for a particular input value shall be displayed, and measured values shall be color coded as they are displayed in real-time according to whether the measured values pass or fail the limits. Calibration standards will be provided by CCAD for temperature, pressure, voltage and frequency. Special or unusual calibration requirements shall be addressed and provided for by the test cell contractor prior to CDR. Any correction factors used that are accessible via software shall be password protected.

4.5 Self Test

The C&I system must be capable of performing a self test on the control and measurement devices within the system. Smart instrumentation shall have the ability to conduct internal self tests and report the results when the system self test is executed. As a minimum, each channel of the data acquisition system must have the capability to read a built-in test signal, such as a reference voltage, for self test purposes.

4.6 Familiarization and Training

Upon completion of the test cell C&I implementation, the test cell contractor shall familiarize the test cell operators with the sensors, harnessing, and data acquisition instrumentation used on the three different engine types. The test cell contractor shall also be responsible for providing training to the operators on the use of the C&I system, to include normal operations, calibration, self test, diagnostics and repair. The duration of this training period shall be for ten (10) training days for four (4) CCAD students.